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Transmission Performance Through Cascaded 1-nm Arrayed Waveguide Multiplexers at 10 Gb/s

Morten Nissov, *Student Member, IEEE,* Rune J. S. Pedersen, and Bo Foged Jørgensen

***Abstract*— The transmission properties of cascaded arrayed waveguide multiplexers are examined in a recirculating loop experiment. We show that a cascade of 40 multiplexers each with a 3-dB bandwidth of ∼1 nm can be passed penalty-free at 10 Gb/s. Furthermore, we show that the allowable fluctuation of the center frequency for a 10 Gb/s signal is reduced to 24 GHz at bit-error rate (BER) = 10^{-9} for a concatenation of 40 multiplexers**

***Index Terms*— Laser stability, optical fiber communication, optical planar waveguide components, optical propagation, wavelength-division multiplexing.**

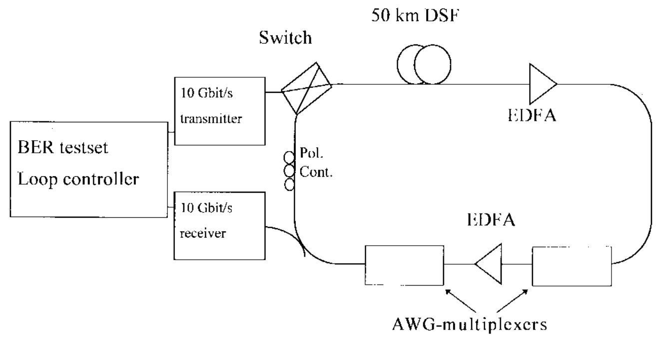

Fig. 1. Schematic diagram of recirculating loop setup for measuring cascading properties of AWG-multiplexers.

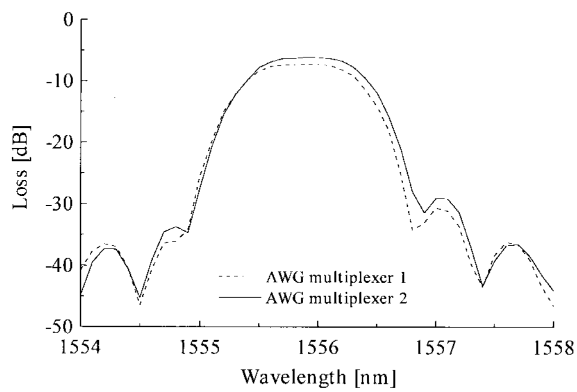

Fig. 2. Measured power transfer function for the two AWG-multiplexers (AT&T x1450D).

I. Introduction

CASCADED optical add–drop multiplexers (OADM) and optical cross-connects (OXC) are key components in optical wavelength division multiplex networks. OADM's with filtering of the passing signals and OXC's can be constructed by use of wavelength division multiplexers (WDM). Cascadability of multiplexers is therefore vital for the network performance.

The actual transfer function of multiplexers is important [1], since the available end-to-end bandwidth between connected nodes in optical networks with cascades of OXC's and OADM's is given by the product of the transfer functions. A cascade of 16 multiplexers in a ring network with a resulting 3-dB bandwidth of 50 GHz was investigated at 10 Gb/s with emphasis on the impact of modulator chirp [2]. In [3], a cascade of up to 15 narrow-band arrayed waveguide (AWG) multiplexers [4] each with a 3-dB bandwidth of 38 GHz was investigated in a recirculating loop experiment at 10 Gb/s. A penalty of 2–3 dB was measured after 10 multiplexers.

In this letter, the cascadability of AWG multiplexers each with a 3-dB bandwidth of ∼1 nm and sharp roll-off characteristics is analyzed experimentally in a recirculating loop at 10 Gb/s. We show that up to 40 multiplexers can be passed penalty-free. Furthermore, the allowable fluctuation of the center frequency (ACF) is examined when up to 60 of these multiplexers are cascaded. The ACF is defined as the range of carrier frequencies for which the 10 Gb/s signal can achieve a bit-error rate (BER) $<10^{-9}$ for a fixed level of received optical power. We show that the ACF is ∼24 GHz when 40 multiplexers are cascaded and that the ACF is reduced to almost zero for a cascade of 60 multiplexers.

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II. Experiment

A recirculating loop experiment at 10 Gb/s is used to investigate the cascadability of arrayed waveguide (AWG) multiplexers. Fig. 1 shows the experimental setup.

A 1.556-μm distributed feedback (DFB) laser is used as signal source and the output light is modulated at 10 Gb/s by an external modulator using a pseudorandom binary sequence with a word length of $2^{31}-1$. The loop consists of 50 km of dispersion shifted fiber (DSF) followed by two AWG-multiplexers. The transfer functions are shown in Fig. 2. The

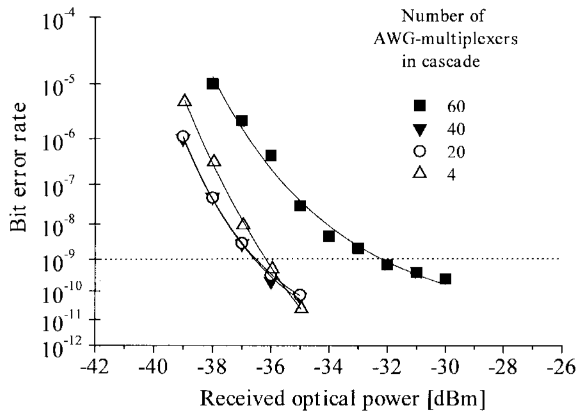
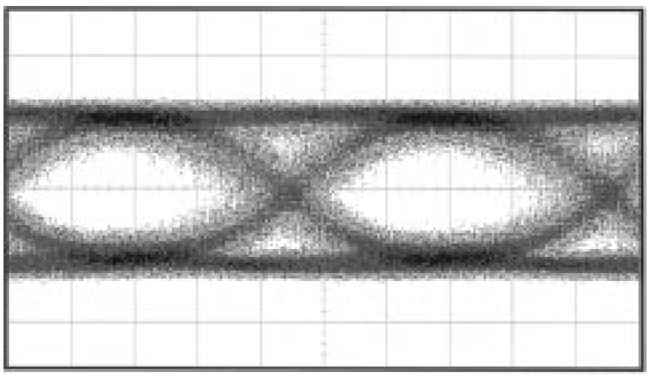
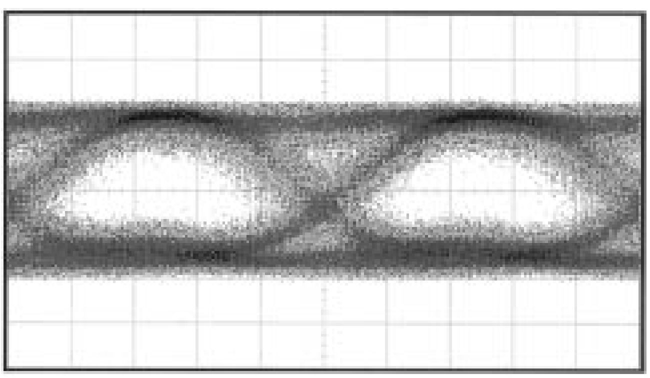


Fig. 3. Measured BER versus received power after transmission through: 4, 20, 40, and 60 AWG-multiplexers.



(a)



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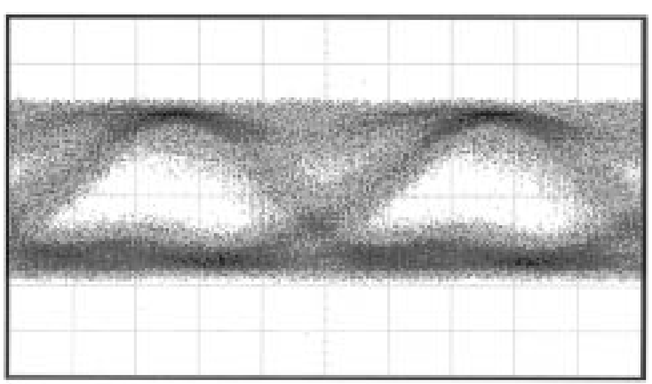


(c)

Fig. 4. Eye diagrams after transmission through (a) 20, (b) 40, and (c) 60 multiplexers. 20 ps/div.

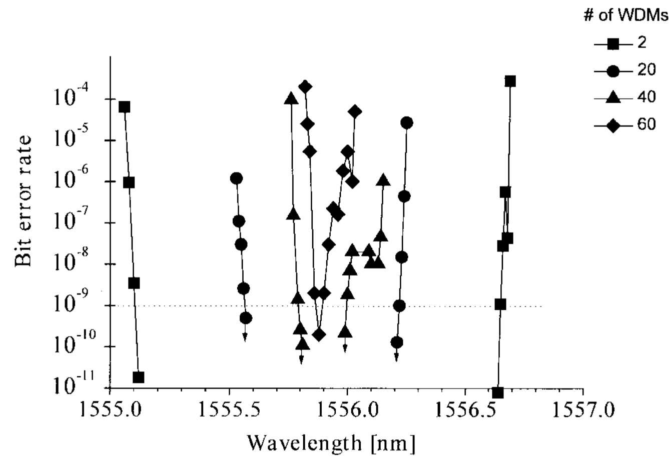


Fig. 5. Allowable fluctuation of center frequency after transmission through 2, 20, 40, and 60 AWG multiplexers.

insertion loss of the two multiplexers are 6.2 and 7.4 dB, respectively, and each has a 3-dB bandwidth of 0.95 nm. The power into the transmission fiber is +1.5 dBm. The two erbium-doped fiber amplifiers (EDFA) compensate losses of the transmission fiber and the multiplexers.

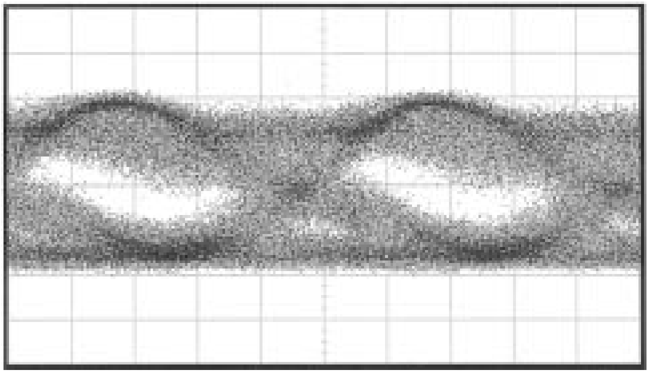
The signal is recirculated in the loop until the desired number of multiplexers have been passed and the BER is measured using an optically preamplified receiver with an optical 3-dB bandwidth of 40 GHz and a back-to-back sensitivity of -37 dBm at BER $= 10^{-9}$.

The ACF is measured by replacing the transmitting DFB laser with a tunable external cavity laser and increasing the 3-dB optical bandwidth of the receiver to 2.3 nm which reduces the back-to-back sensitivity to -35 dBm at BER $=$ 10^{-9}.

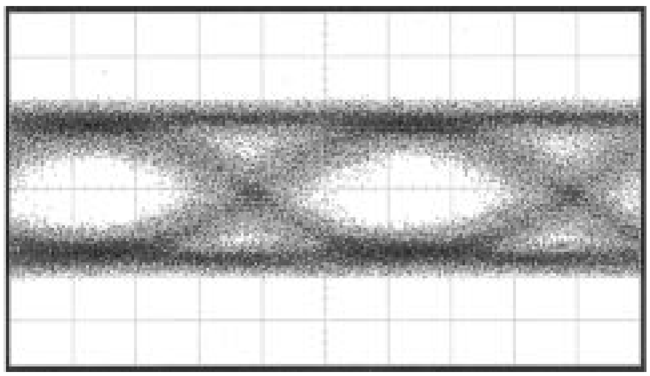
III. RESULTS

BER curves measured for a cascade of 4, 20, 40, and 60 multiplexers are shown in Fig. 3. No significant penalty is seen for cascades of up to 40 multiplexers whereas a cascade of 60 multiplexers results in a penalty of ~4 dB. Eye diagrams for 20, 40, and 60 multiplexers are shown in Fig. 4. For 20 multiplexers (corresponding to 10 loop round-trips) the eye is symmetrical with no pulse distortion and the operation is penalty free. For 40 multiplexers pulse distortion with a flattening of the bottom of the eye can be seen, but the operation is still penalty free. After 60 multiplexers the pulse distortion is more severe and results in a ~4 dB penalty.

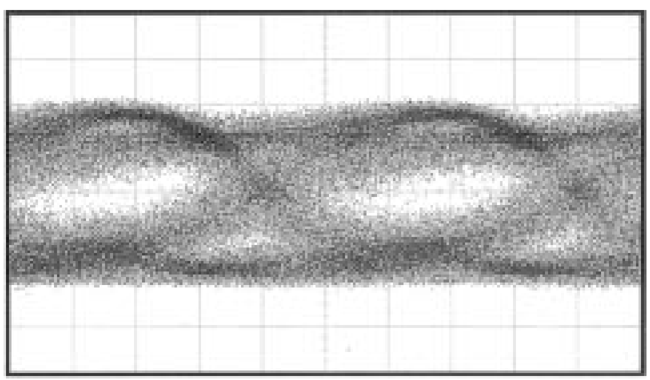
To further investigate the cascade properties of these multiplexers the BER versus wavelength is measured for 2, 20, 40, and 60 multiplexers for a constant receiver input power of -30 dBm. These measurements are shown in Fig. 5. For a cascade of two multiplexers the ACF is ~190 GHz. After only 20 multiplexers the ACF has decreased to 80 GHz and for a cascade of 40 multiplexers the ACF is 24 GHz. For



(a)



(b)



(c)

Fig. 6. Eye diagram at (a) 1555.77 nm, (b) 1555.88 nm, and (c) 1556.16 nm after 40 AWG multiplexers. 20 ps/div.

a cascade of 60 multiplexers the ACF is reduced to almost zero.

Eye diagrams after passing 40 multiplexers are shown in Fig. 6 for a signal wavelength of 1555.77, 1555.88, and 1556.16 nm, respectively. These eye diagrams clearly illustrate the pulse distortions caused by the cascaded multiplexers [5] for the signal being detuned from the optimum wavelength of 1555.86 nm.

IV. Conclusion

It is shown experimentally that at least 40 arrayed waveguide multiplexers with a 3-dB bandwidth of ∼1 nm can be cascaded penalty-free at 10 Gb/s provided that the wavelength of the signal laser is well aligned in the passband of the multiplexers. The requirement for alignment is quantified by measuring the allowable fluctuation of the center frequency after transmission through these 40 arrayed waveguide multiplexers and it is found to be ∼24 GHz.

Acknowledgment

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References

[1] M. J. O'Mahony, "Physical limitations in optical cross-connect networks," presented at the 21st Eur. Conf. Optical Communication ECOC'95, Brussels, Belgium, Sept. 17–21, 1995, paper Tu.B.T.3

[2] F. Shehadeh, T. Suzaki, J.-C. Chiao, K. P. Ho, S. K. Liaw, and R. S. Vodhanel, "Impact of external modulator chirp for 10-Gb/s transmission in an eight-wavelength eight-node WDM ring network," presented at Optical Fiber Communication OFC'97, Dallas, TX, Feb. 16–21, 1997, paper TuE4.

[3] C. Caspar, H.-M. Foisel, R. Freund, U. Krüger, and B. Strebel, "Cacadability of arrayed-waveguide grating (de)multiplexers in transparent optical networks," presented at *Optical Fiber Communication OFC'97*, Dallas, TX, Feb. 16–21, 1997, paper TuE2.

[4] C. Dragone, "An $N \times N$ optical multiplexer using a planar arrangement of two star couplers," *IEEE Photon. Technol. Lett.*, vol. 3, no. 9, pp. 812–815, Sept. 1991.

[5] N. N. Khrais, F. Shehadeh, J.-C. Chiao, R. S. Vodhanel, and R. E. Wagner, "Multiplexer eye-closure penalties for 10 Gb/s signals in WDM networks," presented at *Optical Fiber Communication OFC'96*, San Jose, CA, Feb. 25–Mar. 1, 1996, paper PD33.